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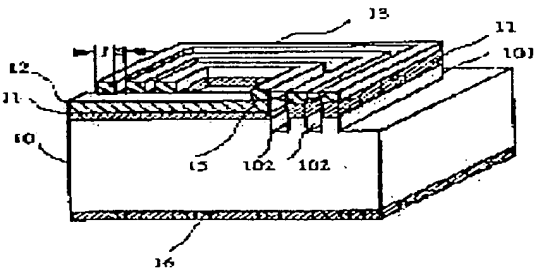
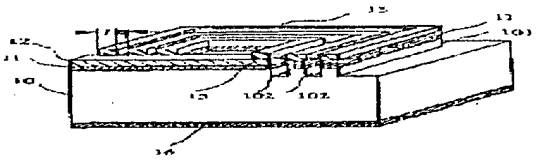
HASE HIDEKAZU

(54) INDUCTOR ELEMENT AND MANUFACTURE THEREOF

(57)Abstract:
PURPOSE: To provide an inductor element having a small size and a low loss for a monolithic microwave IC.
CONSTITUTION: In order to reduce an electric line of force entering a semiinsulating semiconductor substrate 10 of a high specific permittivity, a groove 102 is made, capacitance



C1 of a second wiring metal layer 13 which is a parasitic capacity is sharply reduced. Thereby, an inductor element having a fixed inductance covering a wide band and a low loss can be prepared. Further, a monolithic microwave IC can be made to increase gain, to decrease power consumption and to enlarge band.



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* NOTICES *

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CLAIMS

[Claim(s)]
[Claim 1] The inductor element characterized by removing the aforementioned substrate located in the gap between the wiring layers which constitute the aforementioned inductor element in the inductor element formed on the substrate to a part of the depth.
[Claim 2] The inductor element whose aforementioned substrate is a half-insulation semiconductor substrate in a claim 1.
[Claim 3] The inductor element from which the aforementioned wiring layer is the circular shape of a coil, the square shape of a coil, and the shape of a polygonal coil in the claim 1.
[Claim 4] The inductor element from which the aforementioned wiring layer is a MIANDA pattern in the claim 1.
[Claim 5] The inductor element from which the aforementioned wiring layer is a S character pattern in the claim 1.
[Claim 6] The inductor element characterized by removing the aforementioned substrate located in the both sides of the wiring layer which constitutes the aforementioned inductor element in the linear inductor element formed on the substrate to a part of the depth.
[Claim 7] The inductor element which filled up the slot of the substrate removed by some of Mr. Fukashi with the insulator which has low specific inductive capacity rather than the aforementioned substrate in the claim 1.
[Claim 8] The manufacture method of the inductor element which consists of a process which forms the wiring layer for inductor elements on a substrate, and a process which removes the aforementioned substrate located between the lines of the aforementioned wiring layer to a part of depth, and trenches at least.
[Claim 9] The manufacture method of the inductor element which consists of the

process which forms the wiring layer for inductor elements on a substrate, a process which removes the aforementioned substrate located between the lines of the aforementioned wiring layer to a part of depth, and trenches, and a process which fills up the aforementioned slot with the insulator which has specific inductive capacity lower than the aforementioned substrate at least.
[Claim 10] The monolithic microwave-integrated-circuit element containing an inductor element according to claim 1.

[Translation done.]

* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] this invention relates to the element structure and its manufacturing method of the inductor element used for adjustment of the RF impedance in the integrated circuit which operates by microwave ranges, such as mobile communications, satellite communication, and satellite broadcasting.
[0002]
[Description of the Prior Art] The active element which carries out high frequency operation for realizing a RF circuit until now, and passive elements, such as an inductor element for impedance matching and capacity, were individually assembled on wiring substrates, such as ceramics. However, since the adjustment property changed with the assembly position, it was a high yield and it was very difficult to mass-produce. In order to solve this fault, monolithic microwave IC (Monolithic Microwave IntegratedCircuit) which builds active elements, such as passive elements, such as an inductor element, capacitative element, and resistance, a transistor, and diode, on half-insulation compound semiconductor substrates, such as GaAs and InP, is put in practical use. For the inductor element used here, low-loss-izing for the miniaturization for raising the degree of integration of IC and the formation of high interest profit of IC, and low-power-izing is indispensable.
[0003] the collection of electronic-intelligence communication society autumn convention drafts entitled "low-power-ization of the low noise GaAs monolithic amplifier for mobile communications" by Hase etc. about highly-efficient-izing of the inductor element used for the conventional monolithic microwave IC, for example -- it is discussed in SC-6-8 (-198 pages - 199 page of 5 **)
[0004] The perspective diagram of the conventional inductor element is shown in drawing 2 . The layer insulation film 11 is put on the half-insulation

semiconductor substrate 10, and the leader line of an inductor element is formed in the first wiring metal layer 12 on it. The metal pattern of a whirl [appearance] in a square is formed of the second wiring metal layer 13 with a conductor spacing s and line breadth l. the first wiring metal layer 11 and the second wiring metal layer 13 -- contact -- electrical installation is made in the hole 15 The intersection between the aforementioned wiring metal layers has the air bridge structure 14 insulated with the air of specific-inductive-capacity epsilonr=1 in order to reduce the parasitic capacitance during wiring.

[0005] 16 is a rear-face electrode.

[0006] Moreover, in a circuit design, this inductor element is dealt with as a concentrated-constant element, and is expressed by the equal circuit model as shown in drawing 3 . Drawing 3 is used for below and conditions required for the improvement in a performance of an inductor element are stated to it. This drawing (a) expresses an inductor element using an inductance L, and the parasitism resistance R and parasitic capacitances C1, C2, and C3.

[0007] Generally, the resistance in the RF of a conductor becomes larger than direct current resistance. this -- a RF -- a conductor -- the distribution of the current in a cross section is not uniform, and it is for the skin effect to which current concentrates on marginal one and flows from the interior of a conductor The parasitism resistance R of an inductor element is expressed like a-one number for the skin effect of a wiring metal layer, and it turns into high resistance, so that frequency becomes high.

[0008]

[Equation 1]

$R(f) \propto \sqrt{f}$

..... (数1)

ここで　R；寄生抵抗
f；周波数

[0009] For reduction of Resistance R, the low metal of electric resistance, such as Au, Ag, Cu, and aluminum, is used for a wiring metal layer, and it can solve by attaining optimization of the wiring width of face l and wiring thickness.

[0010] On the other hand, C1 is line capacity and is the sum of the capacity of the intersection of the first metal wiring layer 12 in drawing 2 , and the second metal wiring layer 13, and the line capacity which the spiral portion itself made in the second metal wiring layer 13 has. C2 and C3 are substrate capacity formed by the rear-face electrode 16 and the second metal wiring layer 13 through the half-insulation semiconductor substrate 10. Since the problem of a parasitic

capacitance is clarified, if this equal circuit is further simplified like drawing 3 (b), the impedance Z of an inductor element can be expressed with several 2.

[0011]

[Equation 2]

$$Z(f) = R'(f) + j\omega L'(f)$$

..... (数2)

ここで　R'；等価直列抵抗
L'；等価リンダクタンス
f　；周波数
$\omega = 2\pi f$

[0012] Each of equivalent inductance L' and equivalent-series-resistance R' has frequency dependence here. Moreover, the resonance frequency fr used as the acutance Q of resonance and Q= 0 is expressed with the following several 3 and several 4 as a performance index of an inductor element. It can be called such a good inductor element that Q and fr are large so that clearly from a formula.

[0013]

[Equation 3]

$$Q(f) = \frac{\omega L'(f)}{R'(f)}$$

..... (数3)

ここで　R'；等価直列抵抗
L'；等価インダクタンス
f　；周波数
$\omega = 2\pi f$

[0014]

[Equation 4]

$$fr = \frac{1}{2\pi\sqrt{LC_1}}$$

..... (数4)

ただし　$C_1 \gg C_2, C_3$　の時、
ここで　C_1；線間容量
L；インダクタンス

[0015] Drawing 4 shows the frequency dependence of L' in an inductor element, R', and Q. Although L' and R' show the inclination which increases with frequency, an ideal inductor element has fixed equivalent inductance L' over a wide band, and it is desirable to have low equivalent-series-resistance R'. In addition, the frequency characteristic of equivalent-series-resistance R' is steeper than the frequency characteristic of R, and it turns out that the effect of a parasitic capacitance other than the skin effect is included. That is, to

highly-efficient-izing of an inductor element, reduction of a parasitic capacitance is indispensable.

[0016] Moreover, it turns out also from drawing that the effect of this L' and R' can be represented by the performance index Q. That is, the inductor element which shows high Q value is required when producing highly efficient monolithic microwave IC.

[0017]

[Problem(s) to be Solved by the Invention] An ideal inductor element is equivalent inductance L"s being fixed and having low equivalent-series-resistance R' over a wide band. Furthermore, equivalent-series-resistance R' has a upward tendency still more intense than R because of a parasitic capacitance. For reduction of R, it is [that what is necessary is just to reduce the direct current resistance of the wiring metal layer of an inductor element] solvable with expansion of the wiring width of face l, and optimization of wiring thickness using the metal wiring with sufficient electrical conductivity. On the other hand, reduction of line capacity is required for reduction of a parasitic capacitance, although it can attain by extending the conductor spacing s of the second wiring metal layer 13 (drawing 2), an inductor element enlarges this solution and it is not desirable.

[0018] The purpose of this invention is the acutance Q of high resonance, and the high resonance frequency fr. It is in offering the small inductor which it has.

[0019]

[Means for Solving the Problem] When the structure of drawing 2 is examined in detail, concentrating the line of electric force produced between lines on the half-insulation semiconductor substrate 10 with high specific inductive capacity, and making the parasitic capacitance increase understands. It is [in a half-insulation GaAs substrate] as high as epsilonr=12.6 at specific-inductive-capacity epsilonr=12.5 and a half-insulation InP substrate. For this reason, in order to reduce line capacity C1, it is required to reduce the line of electric force which enters into the half-insulation semiconductor substrate 10. It is required to keep away, as long as the wiring layer which constitutes an inductor element for that purpose is made from the half-insulation semiconductor substrate 10.

[0020] Drawing 1 is the perspective diagram of the spiral inductor by this invention. The half-insulation semiconductor substrate 10, the layer insulation film 11, the first, and second wiring metal layers 12 and 13 are arranged as shown in drawing, and it leaves the insulator layer 11 and the half-insulation semiconductor substrate 101 which are supporting the wiring metals 12 and 13,

and the slot 102 is formed in the half-insulation semiconductor substrate 10.
[0021]
[Function] In order to reduce the line of electric force which enters into the half-insulation semiconductor substrate 10 with high specific inductive capacity, it trenched [102] and the line capacity of the second wiring metal layer 13 has been reduced. Consequently, line capacity C1 could be reduced sharply, and over the wide band, equivalent inductance L' was fixed and has created the small inductor element which has low equivalent-series-resistance R'. Q value was also able to improve sharply compared with the conventional inductor element.
[0022]
[Example]
(Example 1) Drawing 5 is process drawing of the inductor element by this invention, and explains the manufacture method in detail below.
[0023] (a) the half-insulation semiconductor substrates 20 top, such as GaAs and InP, -- SiO2 etc. -- 600nm of insulator layers 21 is put, and the first metal wiring layer 22 is formed by the metal membrane which has three layer structures of for example, lower shell Mo/Au/Mo (150nm / 1.0 micrometers / 50nm) Wiring width of face uses 10 micrometers - 40 micrometers. the second insulator layer 23, for example, SiO2 and SiN, -- after 600nm covering and a phot usual lithography technology -- using -- contact -- opening of the hole 25 is carried out 24 expresses a photoresist.
[0024] (b) Next, form the ground metal membrane 26 for electrolysis plating by the bilayer film of the lower shells Ti (20nm)/nickel (150nm). A vacuum deposition and a spatter are used as membranous means forming. Next, in order to form the second wiring metal layer with selection plating, the pattern of photoresist 24' is formed as mask material.
[0025] (c) Form the second wiring metal layer 27 in a mask for the pattern of photoresist 24' by the selection electrolysis galvanizing method. The metal to galvanize has good Au, Ag, Cu, etc. which have high electrical conductivity. Line breadth l and a conductor spacing s use 4-16 micrometers.
[0026] (d) It is CHF3 about the second insulator layer 23 and the first insulator layer 21 at ion milling in the ground metal membrane 26 for electrolysis plating, using the second wiring metal layer 27 as a mask for photoresist 24' after removal by resist ablation material. The dry etching using gas +C2F6 gas removes one by one. Furthermore, the substrate of GaAs is **********ed a depth of 8 micrometers - 20 micrometers using SiCl4 gas +SF6 gas, and a slot 28 is formed.
[0027] In the case of an InP substrate, CH4 gas +H2 gas etc. is used.
Furthermore, although not shown in drawing, you may also embed this slot 28 by the resin in which low specific inductive capacity, such as PIQ and SAITOPPU

(tradename of the fluorine system resin of Asahi Chemical Industry), is shown. Lamination of the half-insulation semiconductor substrate 20 is carried out to the last to 100 micrometers - 200 micrometers, and the rear-face electrode 29 is put on the rear face.

[0028] Drawing 6 compares the performance about wiring width of face of l= 18 micrometers, and the inductor element (a) by this invention which **********ed the inductor element (b) of structure, and the half-insulation GaAs substrate 8 micrometers conventionally about the spiral inductor element of L=10nH by the number-of-turns 6 turn of s= 14 micrometers of conductor spacings. The items to compare are L', R', and Q. The range of L=L' is wide and, as for the inductor element by this invention, it turns out that equivalent-series-resistance R' is also stopped comparatively low. 21 improves also from Q value 15 in near the frequency of f= 2GHz used by mobile communications. Moreover, line capacity C1 is 0.19pF of the conventional inductor element. What it receives and is depended on this invention is reduced to 0.049pF. Corresponding to it, resonance frequency fr is 3.65 to 7.15GHz. It is improved.

[0029] Drawing 7 shows the etching depth of a half-insulation GaAs substrate, and the relation of Q value about the inductor element of 6 turns by wiring width of face of l= 18 micrometers, and s= 14 micrometers of conductor spacings. It turns out that the upward tendency of Q is seen for the depth to 20 micrometers, and it is saturated soon. Even if this digs a substrate more than a certain depth, line capacity is in agreement with the ability not to decrease.

[0030] (Example 2) Cross-section process drawing of monolithic microwave IC of drawing 8 is used for below, and one example of this invention is explained to it in detail.

[0031] (a) Prepare the wafer with which GaAsFET31, the MIM (Metal-Insulator-Metal) capacity 32, resistance 35, and the wiring layer 34 were formed on the half-insulation GaAs substrate 30. GaAsFET31 is AuGe/W/nickel/Au about the source electrode 310 and the drain electrode 312 in n+ and n layers by the ion implantation method, and forms the gate electrode 311 by aluminum. The MIM capacity 32 is the sandwich structure which sandwiched the plasma SiN film 321 by the Mo/Au layer of aluminum layer of the lower layer electrode 320, and the first wiring metal layer 34. Resistance 35 is n+. The ohmic electrode 351 is formed in a layer by AuGe/W/nickel/Au. First wiring metal layer 34' is the leader line of an inductor element, and 35 is an insulator layer.

[0032] (b) insulator layer 35' -- contact after covering -- carry out opening of the hole 36 and form the coil portion of an inductor element by the second wiring

metal layer 37 by selection gilding As for the thickness of gilding, 8 micrometers, and the line/conductor spacing of a coil used 6 micrometers / 4 micrometers.
[0033] (c) Use as an etching mask the coil portion of the inductor element formed of a photoresist 382 and gilding, and ********** an insulator layer 35 and 35'. Furthermore, the half-insulation GaAs substrate 30 is **********ed a depth of 10 micrometers, and the inductor element 38 is formed for ** with a trench 381 between coils. Finally, the half-insulation GaAs substrate 30 is thin-layer-ized to 150 micrometers, and the rear-face electrode 39 is put.
[0034] The performance of the low noise amplifier created through the above process is described below. Capacity and an inductor element are used for the I/O impedance matching circuit used for monolithic microwave IC, and the low-loss-izing is important for it for circuits, such as a low noise amplifier. That is, if equivalent-series-resistance R' of the inductor element used for a matching circuit is large, the gain of a circuit will fall. A noise figure also increases and degradation of a circuit performance is produced as gain furthermore fell. For this reason, the loss by the inductor element has the problem of degrading the noise figure which can be offered as a circuit compared with the noise figure of GaAsMESFET which is an active element. According to this example, the parasitic capacitance between lines of an inductor element could be reduced, and the highly efficient low noise amplifier has been created.
[0035] That is, conventionally, it is 2mA of consumed electric currents, and is 1.9GHz. Although the power gain of the low noise amplifier which operates was PG=13.5dB and noise figure NF=2.0dB, the low noise amplifier using the inductor element by this example is the same drive current, and PG=14.5dB and NF=1.2dB were obtained. Moreover, the circuit performance of 1.6mA, i.e., even if decreased 20%, when the conventional inductor element (PG=13.5dB and noise figure NF=2.0dB) is used, was obtained in the consumed electric current. By using the inductor element by this example, it is clear that formation of high interest profit of a circuit, low-power-izing, and low noise-ization can be performed. Furthermore, over a large frequency range, since it is fixed, equivalent inductance L' can design microwave circuits, such as high bandwidth amplifier, easily.
[0036] (Example 3) The inductor element cross section of drawing 9 is used for below, and another example of this invention is explained to it in detail.
[0037] (a) The plan of the inductor element by the MIANDA pattern is shown in drawing 9 (a), and the cross section in alignment with the A-A' is shown in this drawing (b). Etching removal of the half-insulation semiconductor substrate 40 located in the periphery of the pattern made with wiring 43 is carried out. The

slot 41 on the substrate is embedded using PIQ44 of epsilonr=3. 42 expresses a layer insulation film and 47 expresses a rear-face electrode.

[0038] (b) The plan of the inductor element by the S character pattern is shown in drawing 9 (c). Etching removal of the half-insulation semiconductor substrate 40 located in the periphery of the pattern made with wiring 45 is carried out, and a slot 46 is formed.

[0039] Improvement in a performance can be aimed at by digging the substrate of the both sides of the strip line also about the linear inductor by the strip line above else.

[0040]

[Effect of the Invention] According to this invention, over a wide band, the line capacity C1 of an inductor element can be reduced sharply, and it is fixed and has low equivalent-series-resistance R', and equivalent inductance L' is small and can produce the inductor element of low loss. Moreover, Acutance Q and resonance frequency fr of resonance can also improve sharply compared with the conventional inductor element. Furthermore, while being able to perform formation of high interest profit of monolithic microwave IC using the inductor by this invention, and low-power-ization, the wide band-ized design of a circuit can be performed easily.

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TECHNICAL FIELD

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PRIOR ART

[Description of the Prior Art] The active element which carries out high frequency operation for realizing a RF circuit until now, and passive elements, such as an inductor element for impedance matching and capacity, were individually assembled on wiring substrates, such as ceramics. However, since the adjustment property changed with the assembly position, it was a high yield and it was very difficult to mass-produce. In order to solve this fault, monolithic microwave IC (Monolithic Microwave IntegratedCircuit) which builds active elements, such as passive elements, such as an inductor element, capacitative element, and resistance, a transistor, and diode, on half-insulation compound semiconductor substrates, such as GaAs and InP, is put in practical use. For the inductor element used here, low-loss-izing for the miniaturization for raising the degree of integration of IC and the formation of high interest profit of IC, and low-power-izing is indispensable.

[0003] the collection of electronic-intelligence communication society autumn convention drafts entitled "low-power-ization of the low noise GaAs monolithic amplifier for mobile communications" by Hase etc. about highly-efficient-izing of the inductor element used for the conventional monolithic microwave IC, for example -- it is discussed in SC-6-8 (-198 pages - 199 page of 5 **)

[0004] The perspective diagram of the conventional inductor element is shown in drawing 2 . The layer insulation film 11 is put on the half-insulation semiconductor substrate 10, and the leader line of an inductor element is formed in the first wiring metal layer 12 on it. The metal pattern of a whirl [appearance] in a square is formed of the second wiring metal layer 13 with a conductor spacing s and line breadth l. the first wiring metal layer 11 and the second wiring metal layer 13 -- contact -- electrical installation is made in the hole 15 The intersection between the aforementioned wiring metal layers has the air bridge structure 14 insulated with the air of specific-inductive-capacity epsilonr=1 in

order to reduce the parasitic capacitance during wiring.
[0005] 16 is a rear-face electrode.
[0006] Moreover, in a circuit design, this inductor element is dealt with as a concentrated-constant element, and is expressed by the equal circuit model as shown in drawing 3 . Drawing 3 is used for below and conditions required for the improvement in a performance of an inductor element are stated to it. This drawing (a) expresses an inductor element using an inductance L, and the parasitism resistance R and parasitic capacitances C1, C2, and C3.
[0007] Generally, the resistance in the RF of a conductor becomes larger than direct current resistance. this -- a RF -- a conductor -- the distribution of the current in a cross section is not uniform, and it is for the skin effect to which current concentrates on marginal one and flows from the interior of a conductor The parasitism resistance R of an inductor element is expressed like a-one number for the skin effect of a wiring metal layer, and it turns into high resistance, so that frequency becomes high.
[0008]
[Equation 1]
$R(f) \propto \sqrt{f}$

..... (数1)

ここで　R；寄生抵抗
f；周波数

[0009] For reduction of Resistance R, a metal with low electric resistance, such as Au, Ag, Cu, and aluminum, is used for a wiring metal layer, and it can solve by attaining optimization of the wiring width of face l and wiring thickness.
[0010] On the other hand, C1 is line capacity and is the sum of the capacity of the intersection of the first metal wiring layer 12 in drawing 2 , and the second metal wiring layer 13, and the line capacity which the spiral portion itself made in the second metal wiring layer 13 has. C2 and C3 are substrate capacity formed by the rear-face electrode 16 and the second metal wiring layer 13 through the half-insulation semiconductor substrate 10. Since the problem of a parasitic capacitance is clarified, if this equal circuit is further simplified like drawing 3 (b), the impedance Z of an inductor element can be expressed with several 2.
[0011]
[Equation 2]

$$Z(f) = R'(f) + j\omega L'(f)$$

..... (数2)

ここで　R' ; 等価直列抵抗
L' ; 等価リンダクタンス
f ; 周波数
$\omega = 2\pi f$

[0012] Each of equivalent inductance L' and equivalent-series-resistance R' has frequency dependence here. Moreover, the resonance frequency fr used as the acutance Q of resonance and Q= 0 is expressed with the following several 3 and several 4 as a performance index of an inductor element. It can be called such a good inductor element that Q and fr are large so that clearly from a formula.
[0013]
[Equation 3]

$$Q(f) = \frac{\omega L'(f)}{R'(f)}$$

..... (数3)

ここで　R' ; 等価直列抵抗
L' ; 等価インダクタンス
f ; 周波数
$\omega = 2\pi f$

[0014]
[Equation 4]

$$fr = \frac{1}{2\pi\sqrt{LC_1}}$$

..... (数4)

ただし　$C_1 \gg C_2, C_3$　の時、
ここで　C_1 ; 線間容量
L ; インダクタンス

[0015] Drawing 4 shows the frequency dependence of L' in an inductor element, R', and Q. Although L' and R' show the inclination which increases with frequency, an ideal inductor element has fixed equivalent inductance L' over a wide band, and it is desirable to have low equivalent-series-resistance R'. In addition, the frequency characteristic of equivalent-series-resistance R' is steeper than the frequency characteristic of R, and it turns out that the effect of a parasitic capacitance other than the skin effect is included. That is, to highly-efficient-izing of an inductor element, reduction of a parasitic capacitance is indispensable.
[0016] Moreover, it turns out also from drawing that the effect of this L' and R' can be represented by the performance index Q. That is, the inductor element

which shows high Q value is required when producing highly efficient monolithic microwave IC.

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EFFECT OF THE INVENTION

[Effect of the Invention] According to this invention, over a wide band, the line capacity C1 of an inductor element can be reduced sharply, and it is fixed and has low equivalent-series-resistance R', and equivalent inductance L' is small and can produce the inductor element of low loss. Moreover, Acutance Q and resonance frequency fr of resonance can also improve sharply compared with the conventional inductor element. Furthermore, while being able to perform formation of high interest profit of monolithic microwave IC using the inductor by this invention, and low-power-ization, the wide band-ized design of a circuit can be performed easily.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] An ideal inductor element is equivalent inductance L"s being fixed and having low equivalent-series-resistance R' over a wide band. Furthermore, equivalent-series-resistance R' has a upward tendency still more intense than R because of a parasitic capacitance. For reduction of R, it is [that what is necessary is just to reduce the direct current resistance of the wiring metal layer of an inductor element] solvable with expansion of the wiring width of face l, and optimization of wiring thickness using the metal wiring with sufficient electrical conductivity. On the other hand, reduction of line capacity is required for reduction of a parasitic capacitance, although it can attain by extending the conductor spacing s of the second wiring metal layer 13 (drawing 2), an inductor element enlarges this solution and it is not desirable.
[0018] The purpose of this invention is the acutance Q of high resonance, and the high resonance frequency fr. It is in offering the small inductor which it has.

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MEANS

[Means for Solving the Problem] When the structure of drawing 2 is examined in detail, concentrating the line of electric force produced between lines on the half-insulation semiconductor substrate 10 with high specific inductive capacity, and making the parasitic capacitance increase understands. It is [in a half-insulation GaAs substrate] as high as epsilonr=12.6 at specific-inductive-capacity epsilonr=12.5 and a half-insulation InP substrate. For this reason, in order to reduce line capacity C1, it is required to reduce the line of electric force which enters into the half-insulation semiconductor substrate 10. It is required to keep away, as long as the wiring layer which constitutes an inductor element for that purpose is made from the half-insulation semiconductor substrate 10.

[0020] Drawing 1 is the perspective diagram of the spiral inductor by this invention. The half-insulation semiconductor substrate 10, the layer insulation film 11, the first, and second wiring metal layers 12 and 13 are arranged as shown in drawing, and it leaves the insulator layer 11 and the half-insulation semiconductor substrate 101 which are supporting the wiring metals 12 and 13, and the slot 102 is formed in the half-insulation semiconductor substrate 10.

[Translation done.]

* NOTICES *

OPERATION

[Function] In order to reduce the line of electric force which enters into the half-insulation semiconductor substrate 10 with high specific inductive capacity, it trenched [102] and the line capacity of the second wiring metal layer 13 has been reduced. Consequently, line capacity C1 could be reduced sharply, and over the wide band, equivalent inductance L' was fixed and has created the small inductor element which has low equivalent-series-resistance R'. Q value was also able to improve sharply compared with the conventional inductor element.

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EXAMPLE

[Example]
(Example 1) Drawing 5 is process drawing of the inductor element by this invention, and explains the manufacture method in detail below.
[0023] (a) the half-insulation semiconductor substrates 20 top, such as GaAs and InP, -- SiO2 etc. -- 600nm of insulator layers 21 is put, and the first metal wiring layer 22 is formed by the metal membrane which has three layer structures of for example, lower shell Mo/Au/Mo (150nm / 1.0 micrometers / 50nm) Wiring width of face uses 10 micrometers - 40 micrometers. the second insulator layer 23, for example, SiO2 and SiN, -- after 600nm covering and a phot usual lithography technology -- using -- contact -- opening of the hole 25 is carried out 24 expresses a photoresist.
[0024] (b) Next, form the ground metal membrane 26 for electrolysis plating by the bilayer film of the lower shells Ti (20nm)/nickel (150nm). A vacuum deposition and a spatter are used as membranous means forming. Next, in order to form the second wiring metal layer with selection plating, the pattern of photoresist 24' is formed as mask material.
[0025] (c) Form the second wiring metal layer 27 in a mask for the pattern of photoresist 24' by the selection electrolysis galvanizing method. The metal to galvanize has good Au, Ag, Cu, etc. which have high electrical conductivity. Line breadth l and a conductor spacing s use 4-16 micrometers.
[0026] (d) It is CHF3 about the second insulator layer 23 and the first insulator layer 21 at ion milling in the ground metal membrane 26 for electrolysis plating, using the second wiring metal layer 27 as a mask for photoresist 24' after removal by resist ablation material. The dry etching using gas +C2F6 gas removes one by one. Furthermore, the substrate of GaAs is **********ed a depth of 8 micrometers - 20 micrometers using SiCl4 gas +SF6 gas, and a slot 28 is formed.
[0027] In the case of an InP substrate, CH4 gas +H2 gas etc. is used.

Furthermore, although not shown in drawing, you may also embed this slot 28 by the resin in which low specific inductive capacity, such as PIQ and SAITOPPU (tradename of the fluorine system resin of Asahi Chemical Industry), is shown. Lamination of the half-insulation semiconductor substrate 20 is carried out to the last to 100 micrometers - 200 micrometers, and the rear-face electrode 29 is put on the rear face.

[0028] Drawing 6 compares the performance about wiring width of face of l= 18 micrometers, and the inductor element (a) by this invention which **********ed the inductor element (b) of structure, and the half-insulation GaAs substrate 8 micrometers conventionally about the spiral inductor element of L=10nH by the number-of-turns 6 turn of s= 14 micrometers of conductor spacings. The items to compare are L', R', and Q. The range of L=L' is wide and, as for the inductor element by this invention, it turns out that equivalent-series-resistance R' is also stopped comparatively low. 21 improves also from Q value 15 in near the frequency of f= 2GHz used by mobile communications. Moreover, line capacity C1 is 0.19pF of the conventional inductor element. What it receives and is depended on this invention is reduced to 0.049pF. Corresponding to it, resonance frequency fr is 3.65 to 7.15GHz. It is improved.

[0029] Drawing 7 shows the etching depth of a half-insulation GaAs substrate, and the relation of Q value about the inductor element of 6 turns by wiring width of face of l= 18 micrometers, and s= 14 micrometers of conductor spacings. It turns out that the upward tendency of Q is seen for the depth to 20 micrometers, and it is saturated soon. Even if this digs a substrate more than a certain depth, line capacity is in agreement with the ability not to decrease.

[0030] (Example 2) Cross-section process drawing of monolithic microwave IC of drawing 8 is used for below, and one example of this invention is explained to it in detail.

[0031] (a) Prepare the wafer with which GaAsFET31, the MIM (Metal-Insulator-Metal) capacity 32, resistance 35, and the wiring layer 34 were formed on the half-insulation GaAs substrate 30. GaAsFET31 is AuGe/W/nickel/Au about the source electrode 310 and the drain electrode 312 in n+ and n layers by the ion implantation method, and forms the gate electrode 311 by aluminum. The MIM capacity 32 is the sandwich structure which sandwiched the plasma SiN film 321 by the Mo/Au layer of aluminum layer of the lower layer electrode 320, and the first wiring metal layer 34. Resistance 35 is n+. The ohmic electrode 351 is formed in a layer by AuGe/W/nickel/Au. First wiring metal layer 34' is the leader line of an inductor element, and 35 is an insulator layer.

[0032] (b) insulator layer 35' -- contact after covering -- carry out opening of the hole 36 and form the coil portion of an inductor element by the second wiring metal layer 37 by selection gilding As for the thickness of gilding, 8 micrometers, and the line/conductor spacing of a coil used 6 micrometers / 4 micrometers.
[0033] (c) Use as an etching mask the coil portion of the inductor element formed of a photoresist 382 and gilding, and ********** an insulator layer 35 and 35'. Furthermore, the half-insulation GaAs substrate 30 is **********ed a depth of 10 micrometers, and the inductor element 38 is formed for ** with a trench 381 between coils. Lamination of the half-insulation GaAs substrate 30 is carried out to the last to 150 micrometers, and the rear-face electrode 39 is put on it.
[0034] The performance of the low noise amplifier created through the above process is described below. Capacity and an inductor element are used for the I/O impedance matching circuit used for monolithic microwave IC, and the low-loss-izing is important for it for circuits, such as a low noise amplifier. That is, if equivalent-series-resistance R' of the inductor element used for a matching circuit is large, the gain of a circuit will fall. A noise figure also increases and degradation of a circuit performance is produced as gain furthermore fell. For this reason, the loss by the inductor element has the problem of degrading the noise figure which can be offered as a circuit compared with the noise figure of GaAsMESFET which is an active element. According to this example, the parasitic capacitance between lines of an inductor element could be reduced, and the highly efficient low noise amplifier has been created.
[0035] That is, conventionally, it is 2mA of consumed electric currents, and is 1.9GHz. Although the power gain of the low noise amplifier which operates was PG=13.5dB and noise figure NF=2.0dB, the low noise amplifier using the inductor element by this example is the same drive current, and PG=14.5dB and NF=1.2dB were obtained. Moreover, the circuit performance of 1.6mA, i.e., even if decreased 20%, when the conventional inductor element (PG=13.5dB and noise figure NF=2.0dB) is used, was obtained in the consumed electric current. By using the inductor element by this example, it is clear that formation of high interest profit of a circuit, low-power-izing, and low noise-ization can be performed. Furthermore, over a latus frequency range, since it is fixed, equivalent inductance L' can design microwave circuits, such as high bandwidth amplifier, easily.
[0036] (Example 3) The inductor element cross section of drawing 9 is used for below, and another example of this invention is explained to it in detail.
[0037] (a) The plan of the inductor element by the MIANDA pattern is shown in drawing 9 (a), and the cross section in alignment with the A-A' is shown in this

drawing (b). Etching removal of the half-insulation semiconductor substrate 40 located in the periphery of the pattern made with wiring 43 is carried out. The slot 41 on the substrate is embedded using PIQ44 of epsilonr=3. 42 expresses a layer insulation film and 47 expresses a rear-face electrode.

[0038] (b) The plan of the inductor element by the S character pattern is shown in drawing 9 (c). Etching removal of the half-insulation semiconductor substrate 40 located in the periphery of the pattern made with wiring 45 is carried out, and a slot 46 is formed.

[0039] Improvement in a performance can be aimed at by digging the substrate of the both sides of the strip line also about the linear inductor by the strip line above else.

[Translation done.]

* NOTICES *

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The perspective diagram of the inductor element by this invention.

[Drawing 2] The perspective diagram of the conventional inductor element.

[Drawing 3] The representative circuit schematic of an inductor element.

[Drawing 4] The property view of the frequency dependence of the equivalent circuit constant of an inductor element.

[Drawing 5] The cross section showing the process of the inductor element of one example by this invention.

[Drawing 6] The performance comparison property view of the inductor element by the former and this invention.

[Drawing 7] The property view showing the depth of flute of an inductor element and the relation of Q value by this invention.

[Drawing 8] The cross section showing the process of monolithic microwave IC of one example by this invention.

[Drawing 9] The cross section of the inductor element of one example by this invention.

[Description of Notations]

10, 101, 40 -- half insulation semiconductor substrate, 11 [-- Second wiring metal layer.] -- A layer insulation film, 12 -- The first wiring metal layer, 13

[Translation done.]

* NOTICES *

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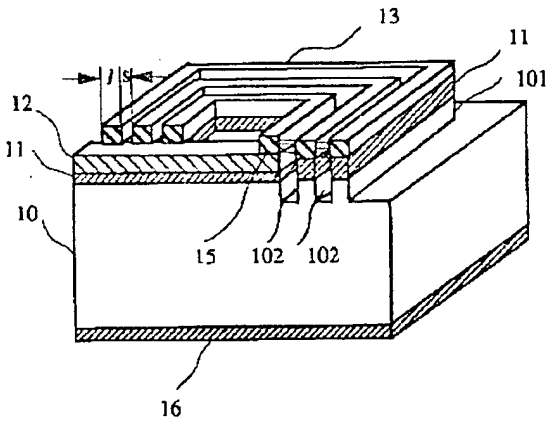
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

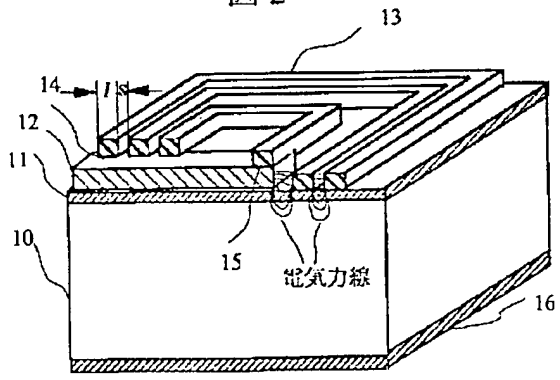
[Drawing 1]

図 1



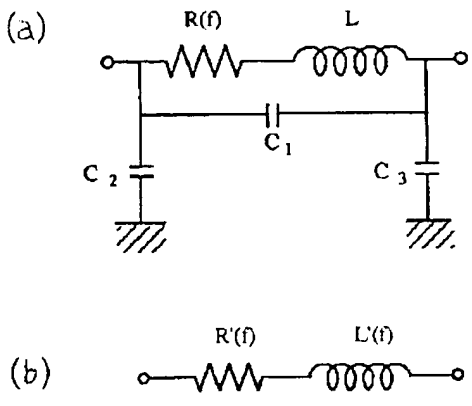
[Drawing 2]

図 2



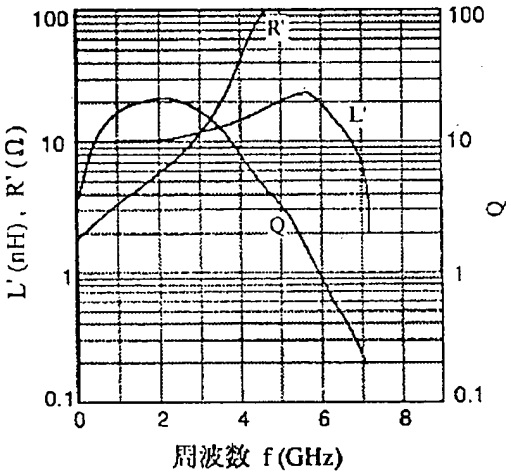
[Drawing 3]

図 3



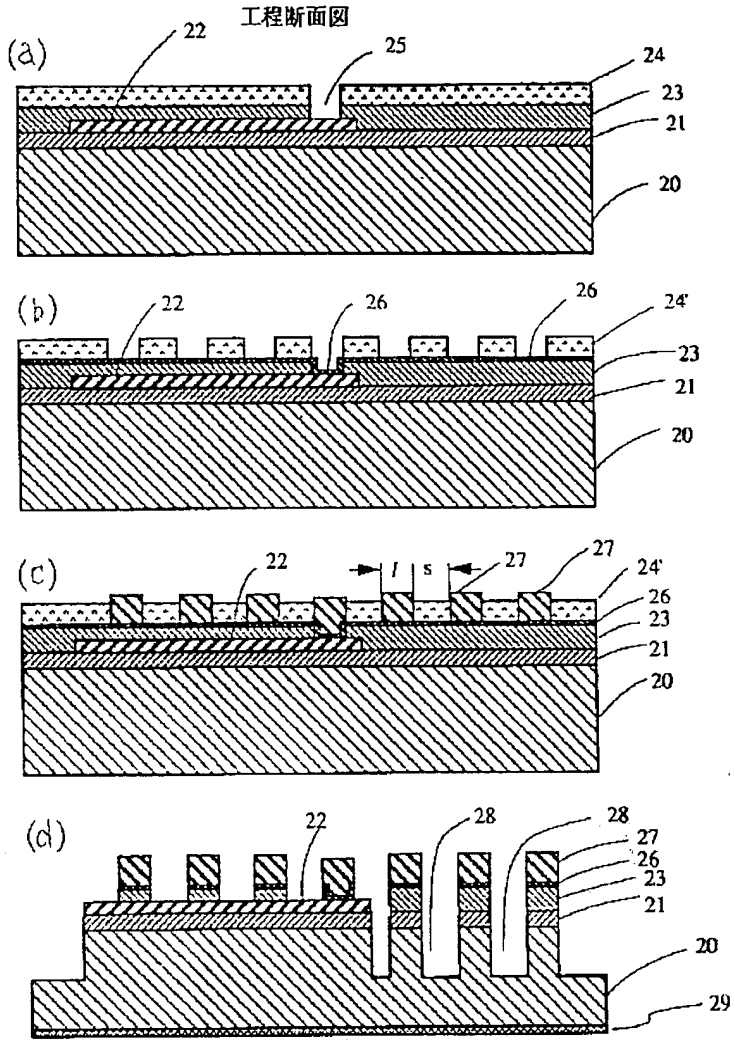
[Drawing 4]

図 4



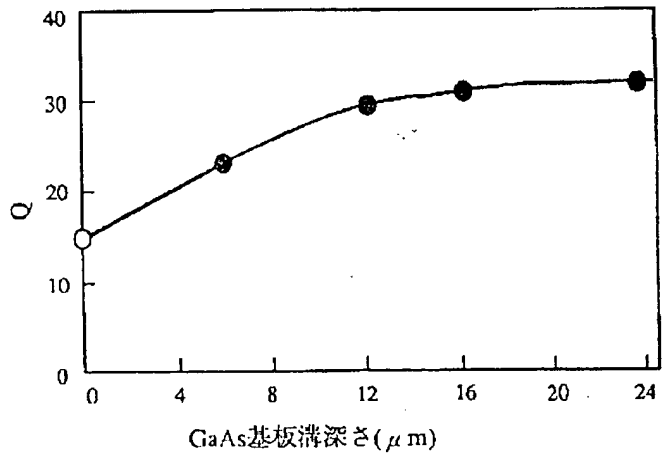
[Drawing 5]

図 5



[Drawing 7]

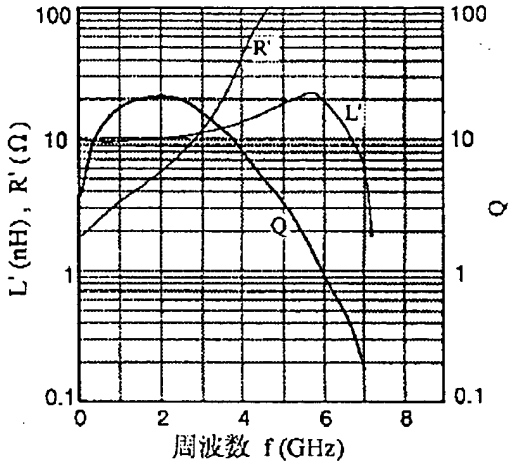
図 7



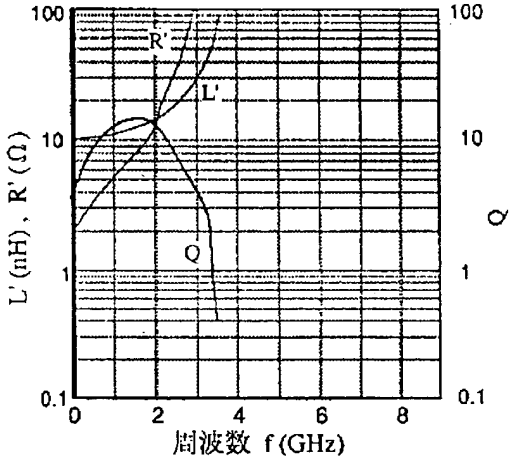
[Drawing 6]

図 6

(a) 本発明によるインダクタ素子の特性



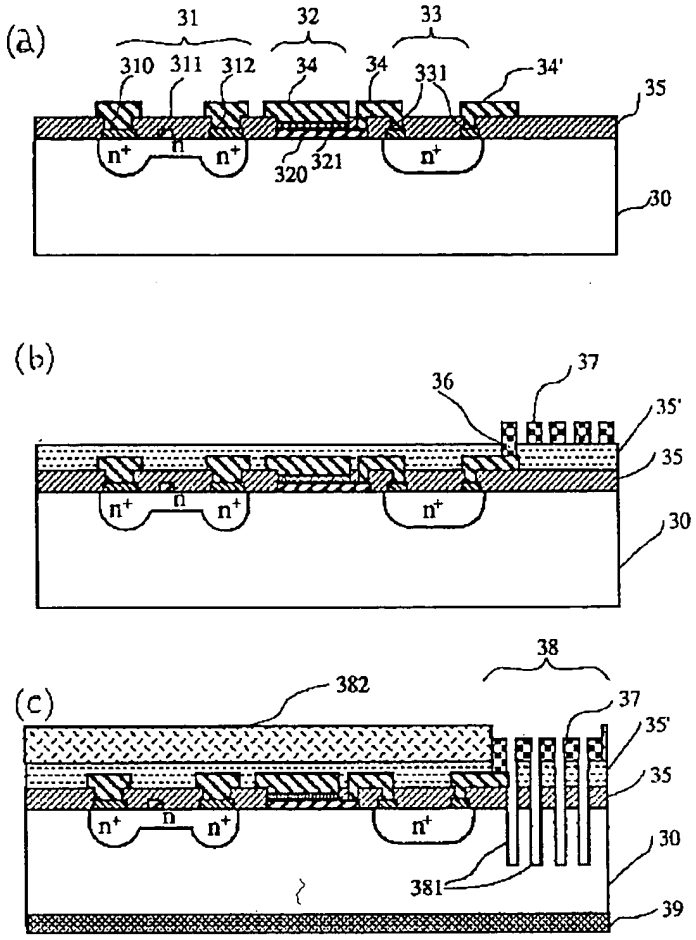
(b) 従来構造のインダクタ素子の特性



[Drawing 8]

図 8

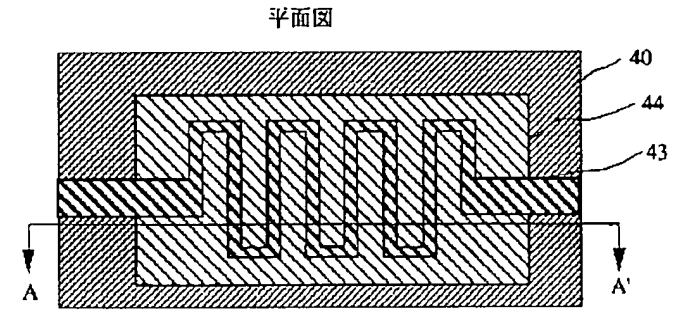
工程断面図



[Drawing 9]

図9

(a)



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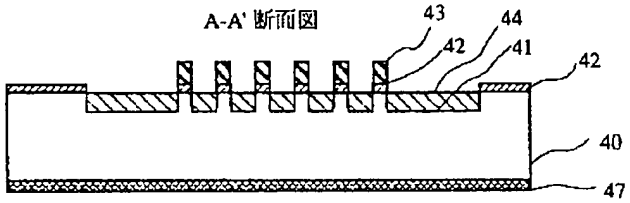
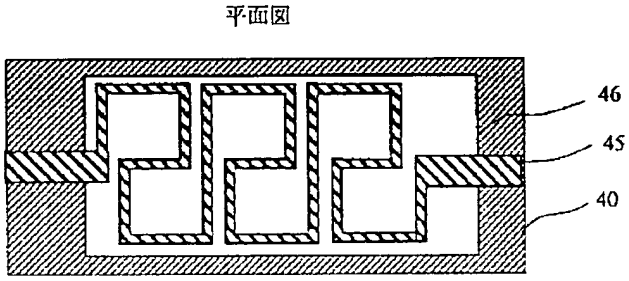


(c)



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